(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 May 2002 (30.05.2002)

PCT

(10) International Publication Number
WO 02/41767 A1

(51) International Patent Classification[7]: A61B 1/04

(21) International Application Number: PCT/KR01/02017

(22) International Filing Date: 22 November 2001 (22.11.2001)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
2000/70725 25 November 2000 (25.11.2000) KR
2001/24390 4 May 2001 (04.05.2001) KR

(71) Applicant *(for all designated States except US)*: **3DMED CO., LTD.** [KR/KR]; 940-319, Seoul National University Research Park, San 4-8, Bongcheon-dong, Kwanak-ku, 151-050 Seoul (KR).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **KOO, Yun-Mo** [KR/KR]; 301, 1638-10, Bongcheon 11-dong, Kwanak-ku, 151-061 Seoul (KR). **SHIN, Yeong-Gil** [KR/KR]; Imkwang Apt. 11-307, Bangbae-dong, Seocho-ku, 137-060 Seoul (KR). **CHUNG, Jin-Wook** [KR/KR]; Sampoong Apt. 19-1101, Seocho 4-dong, Seocho-ku, 137-074 Seoul (KR).

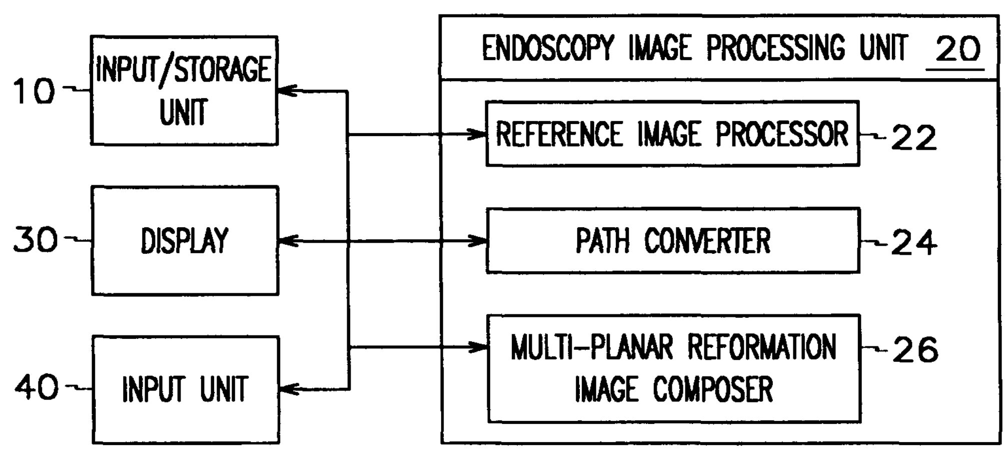
(74) Agent: **PARK, Young-IL**; Hyundai Life Insurance Bldg., 5F, 649-14, Yoksam-dong, Gangnam-gu, Seoul 135-080 (KR).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,

*[Continued on next page]*

(54) **Title:** SYSTEM AND METHOD FOR DISPLAYING A VIRTUAL ENDOSCOPY AND COMPUTER READABLE MEDIUM STORING THEREOF




(57) **Abstract:** A virtual endoscopy system and method, and a computer readable recording medium. A volume rendering image corresponding to a part to be observed is generated from three-dimensional (3D) volume data. The generated volume rendering image, an axial image, a virtual endoscopy image, and a path MPR image are displayed in one screen. The displayed path MPR image is updated as a path is set by a user in either the axial image or the 3D volume rendering image. When it is requested to change the camera position according to the manipulation of the user, virtual endoscopy image data is generated according to the change of the camera position. The virtual endoscopy image and the axial image are updated on the basis of the generated virtual endoscopy image data. As a result, the user can easily define and modify the path using the image generated by volume rendering as a reference image and can three-dimensionally control the direction of the camera on two dimensions without preprocessing on the 3D volume data.

WO 02/41767 A1

GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# System and Method for Displaying a Virtual Endoscopy and Computer Readable Medium Storing thereof

## BACKGROUND OF THE INVENTION

### (a) Field of the Invention

The present invention relates to a virtual endoscopy system and method, and a computer readable recording medium for storing the method. More specifically, the present invention relates to a virtual endoscopy system and method, which are capable of setting a path using a cross-sectional image and a volume rendering image in a virtual endoscope, and a computer readable recording medium for storing the method.

### (b) Description of the Related Art

In general, an image reconstruction system including a virtual endoscopy system has various application fields. In particular, the image reconstruction system can be used in the medical image field for a three-dimensional (3D) human body.

In particular, a 3D medical imaging technique involves generating a three-dimensional image from a series of axial images obtained from Computed Tomography (CT) or Magnetic Resonance Imaging (MRI). Only using 2D axial images makes it difficult to imagine the 3D shape and to reconstruct the arbitrary section, which are very useful for diagnosis. When the 3D medical imaging technique is used, it is possible to find a particular

position and to plan an operation method with the better sense of reality.

Conventional virtual endoscopy systems use axial images in order to control the movement of a virtual camera. However, it is difficult to determine the corresponding camera position for doctors to be observed by using axial images. Also, the systems cannot easily perform automatic navigation.

The improved technique based on the automatic segmentation and surface rendering has been developed. However, automatic segmentation cannot be easily performed especially in a complicated structure. In addition, automatic path generation algorithm is not so perfect to find a path that a user wants to find.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a virtual endoscopy system to set a path on a three-dimensional (3D) volume rendering image without preprocessing, which can reduce time required for diagnoses. And by displaying a multi-planar reformation image including the path,the efficiency of diagnoses can be improved.

It is another object of the present invention to provide a virtual endoscopy method using the virtual endoscopy system.

It is another object of the present invention to provide a computer readable recording medium for storing a program including the virtual

endoscopy method.

In one aspect of the present invention, there is provided a virtual endoscopy system, comprising an input/storage unit for reading or transferring the 3-dimensional volume data from source devices into the target devices for further processing; an endoscopy image processing unit for analyzing and displaying spatial distribution of the characteristics to a 3D image on the basis of data stored in the input/storage unit, processing the 3D image so as to display it as a reference image, generating an endoscopy image along a predetermined path directly displayed on the reference image, and processing the endoscopy image so as to display it; a display for displaying the reference image and the endoscopy image along the path; and an input unit for letting a user designate the path from the reference image.

The endoscopy image processing unit comprises a reference image processor for generating the 3D reference image so as to display it from the volume data stored in the input/storage unit, receiving a predetermined path that passes through an inner structure whose endoscopy image is to be seen through the input methods in the form of predetermined curved line on the reference image, and processing the curved data; a path converter for determining the position of a voxel corresponding to the wall of the inner structure whose endoscopy image is to be seen in the volume data from the path input to the reference image processor, and correcting a path so that the path can actually pass through

the inner structure; and a multi-planar reformation image composer for generating a multi-planar reformation image including the path along the corrected path obtained by the path converter.

In another aspect of the present invention, there is provided a virtual endoscopy method for storing primitive image data, classifying the density value of the stored primitive image data, and displaying a virtual endoscope, comprising (a) generating a volume rendering image corresponding to a part to be observed from the 3D volume data; (b) displaying the generated volume rendering image, an axial image, a virtual endoscopy image, and a path MPR image; (c) updating display of the path MPR image as a path is set in either the axial image or a 3D volume rendering image according to the manipulation of a user; (d) checking whether the position of a camera is requested to be changed according to the manipulation of the user; and (e) generating virtual endoscopy image data according to the change of the camera position and updating the virtual endoscopy image and the axial image on the basis of the generated virtual endoscopy image, when the position of the camera is requested to be changed.

The camera displays the volume rendering image, the axial image, the virtual endoscopy image, and the path MPR image using a predetermined viewing vector; updates the volume rendering image, the axial image, the virtual endoscopy image, and the path MPR image using a changed viewing vector obtained by controlling the viewing vector; and

obtains a 3D image effect on the axial image.

In another aspect of the present invention, there is provided a computer readable recording media for storing a program including a method for displaying a virtual endoscope by storing primitive image data and classifying the density value of the stored primitive image data, comprising (a) generating a volume rendering image corresponding to a part to be observed from the 3D volume data; (b) displaying the generated volume rendering image, an axial image, a virtual endoscopy image, and a path MPR image; (c) updating display of the path MPR image as a path is set in either the axial image or a 3D volume rendering image according to the manipulation of a user; (d) checking whether the position of a camera is requested to be changed according to the manipulation of the user; and (e) generating virtual endoscopy image data according to the change of the camera position and updating the virtual endoscopy image and the axial image on the basis of the generated virtual endoscopy image, when the position of the camera is requested to be changed.

According to the virtual endoscopy system and method, and a computer readable recording medium for storing the method, a user can easily define and modify a path and control the direction of the camera from two dimensions to three dimensions using an image generated by volume rendering without preprocessing with respect to the 3D volume data as a reference image.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention, and, together with the description, serve to explain the principles of the invention:

FIG. 1 shows a virtual endoscopy system according to an embodiment of the present invention;

FIG. 2 shows an example of a screen of a virtual endoscopy system according to the present invention;

FIG. 3 is a flowchart for explaining a virtual endoscopy method according to the present invention;

FIG. 4 is a flowchart for explaining S400 of FIG. 3 in more detail;

FIG. 5 is a flowchart for explaining S420 of FIG. 4 in more detail

FIG. 6 explains processes of searching for the position of an actual inner organ in three dimensions from a point input to a reference image in the virtual endoscopy system according to the present invention;

FIG. 7 explains the generation of a cross-sectional reformation image including a path according to the present invention

FIG. 8 explains the generation of a cross-sectional reformation image parallel to or vertical to the path according to the present invention;

FIG. 9 explains the three-dimensional controlling of a camera in two dimensions according to the present invention;

FIG. 10 shows a three-dimensional (3D) volume rendering image

used as the reference image of the virtual endoscopy system according to the present invention;

FIG. 11 shows an example of loading a screen provided by a preferred virtual endoscopy system according to the present invention on the basis of the 3D volume rendering image of FIG. 10; and

FIG. 12 shows a screen providing a function of arbitrarily modifying the path once designated by a user in FIG. 11 in the preferred virtual endoscopy system according to the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following detailed description, only the preferred embodiment of the invention has been shown and described, simply by way of illustration of the best mode contemplated by the inventor(s) of carrying out the invention. As will be realized, the invention is capable of modification in various obvious respects, all without departing from the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not restrictive.

FIG. 1 shows a virtual endoscopy system according to an embodiment of the present invention.

Referring to FIG. 1, a virtual endoscopy system according to the present invention includes an input/storage unit 10, an endoscopy image processing unit 20, a display 30, and an input unit 40.

The input/storage unit 10 reads or transfers the 3-dimensional volume data from source devices into the target devices for further processing. For example, in the case of receiving and storing the volume data as a set of results from computed tomography (CT) or magnetic resonance imaging (MRI) section scanning, the input storage unit can be formed of access hardware for receiving data from the respective measurement apparatuses and a hard disk or a memory device for storing the data. In the case of storing the measured result in another storage medium and reading the measured results or storing the measured results in a storage medium such as a hard disk, the input storage unit 10 can be formed of access hardware for reading data from storage apparatuses inside/outside the three-dimensional image processing system and a hard disk or a memory device for storing the data.

The endoscopy image processing unit 20 includes a reference image processor 22, a path converter 24, and a multi-planar reformation image composer 26. The endoscopy image processing unit 20 analyzes and displays the spatial distribution of the characteristics as a 3D image on the basis of the data stored in the input/storage unit 10, processes the 3D image so as to display it as a reference image, generates an endoscopy image along a predetermined path directly displayed on the reference image, and processes the endoscopy image to be displayed.

More specifically, the reference image processor 22 displays the 3D reference image from the volume data stored in the input/storage unit

10, receives a predetermined path passing through an inner structure whose endoscopy image is desired to be seen through the input unit 40 in the form of predetermined curved data on the reference image, and processes the curved data.

The path converter 24 determines the position in the volume data of a voxel corresponding to the wall of the inner structure whose endoscopy image is to be seen from the path input to the reference image processor 22, and corrects the path so that the inner structure can actually pass through the path due to the position of the voxel.

The multi-planar reformation image composer 26 generates a multi-planar reformation image including the path according to the corrected path obtained by the path converter 24.

The endoscopy image processing unit 20 is a means for calculating and processing the volume data. The endoscopy image processing unit 20 can be realized by a computer that can perform a series of calculation processes, a set of computers in which data can be exchanged between computers, and an application-specific integrated circuit (ASIC).

The display 30 displays the reference image and displays the endoscopy image along the path. The input unit 40 lets a user designate the path from the reference image.

FIG. 2 shows an example of a screen of the virtual endoscopy system according to the present invention.

Referring to FIG. 2, the screen of the virtual endoscopy system

according to the present invention includes the four viewers of a 3D volume rendering image 100, an axial image 200, a virtual endoscopy image 300, and a path MPR image 400. Volume rendering refers to the work of extracting visual image information required for various applications from volume data of a 3D space.

When a camera is set by the manipulation of a user in the 3D volume rendering image 100 of a displayed screen, the axial image 200 and the virtual endoscopy image 300 are generated, to thus update a previously displayed image. Also, as a path is set by the manipulation of the user, the path MPR image 400 is generated in connection with the path, to thus update the previously displayed image.

As the camera is set by the manipulation of the user in the displayed axial image 200, the path MPR image 400 is generated, to thus update the previously displayed image. As the path is set by the manipulation of the user, the virtual endoscopy image 300 is generated, to thus update the previously displayed image.

Operations for displaying the various images will now be described in more detail.

FIG. 3 is a flowchart for explaining a virtual endoscopy method according to the present invention.

Referring to FIGs. 2 and 3, the scan data of the human body structure obtained through apparatuses such as the CT and the MRI, that is, primitive image data, is stored (S100).

The 3D volume rendering image 100 is generated so that an observed part can be clearly shown by a method of classifying a density value in real time and deleting unnecessary parts in order to look at the structure to be observed according to the manipulation of the user (S200).

The 3D volume rendering image 100, the axial image 200, the virtual endoscopy image 300, and the path MPR image are displayed on the four viewers shown in FIG. 2 (S300).

A corresponding path is set as a path set request, and is input according to the manipulation of the user on the axial image or the 3D volume rendering image (S400). A path can be set or changed on the axial image. However, it is preferred that a user directly sets a path on the 3D volume rendering image in the form of an arbitrary straight or curved line for the convenience of the user.

An image is generated along the path set by mapping an axial point designated by the 3D volume rendering image 100 to the central point of the inner structure to be seen, that is, to a 3D point, and is displayed (S500). The path MPR image 400 shown in FIG. 2 will be preferably updated.

It is checked whether the camera is controlled by the manipulation of the user (S600). When it is determined that the camera is not controlled, the process returns to S500 and an image is continuously displayed. When it is determined that the camera is controlled, the virtual endoscopy image 300 controlled by the camera is generated (S700). At this time, the

controlled camera is a kind of a virtual camera that moves on the endoscopy image, that is, the point of view of the eyes of the user. It is possible to freely control the view angle of the camera. The volume rendering image is reformed from the primitive image data in connection with the freely controlled view angle of the camera, and is displayed.

The axial image 200 and the virtual endoscopy image 300 are updated and displayed (S800).

It is checked whether the 3D volume rendering image 100 is re-manipulated (S900). When it is determined that the 3D volume rendering image is re-manipulated, the process returns to S200.

A path-setting method that is a characteristic of the present invention will now be described in detail with reference to the attached drawings.

FIG. 4 is a flowchart for explaining S400 of FIG. 3 in more detail.

Referring to FIG. 4, as points are designated by the manipulation of the user on the axial image or the 3D volume rendering image for the reformation of the path (S410), curved control points are added (S420).

A path is generated using the formula of a 3D curved line (S430). Corresponding points are stored in a predetermined path material structure along a corresponding curved line at predetermined intervals, for example, at each one voxel interval (S440). The various points stored in the path material structure will be used as data corresponding to the reset path, in response to which path MPR images will be updated and displayed in S500.

In S410, when the user uses the axial image 200 shown in FIG. 2 as the reference image in order to obtain the virtual endoscopy image or the path MPR image, it is possible to know the voxel where the axial image exists together with the (x, y) data of the displayed reference image, that is, the axial image. Therefore, it is possible to know the z coordinate value. Accordingly, it is possible to know the 3D coordinate (x, y, z), which is the position of the axial image on the entire volume data.

However, when the user uses the 3D image as the reference image in order to obtain the virtual endoscopy image or the path MPR image, the z value must be efficiently recognized.

A method for recognizing the z value when the user uses the 3D image as the reference image, which is another characteristic of the present invention, will now be described in more detail.

FIG. 5 is a flowchart for explaining S420 of FIG. 4 in more detail. In particular, processes of mapping the axial point designated in the 3D volume rendering image to the central point of the structure will be described. FIG. 6 explains processes of searching for the position of an actual inner organ in three dimensions from a point input to a reference image in the virtual endoscopy system according to the present invention.

Referring to FIGs. 5 and 6, as a mouse is input to the axial image displayed by the 3D volume rendering according to the manipulation of the user (S4210), the minimum value and the maximum value of a depth to be examined are set (S4220).

The point of a plane coordinate system is converted into the point of the spatial coordinate system by multiplying time inverse matrices by each other (S4230).

A predetermined ray is casted from the center of projection (S4240). The casted ray is a virtual straight ray line from a virtual 3D space rather than physicalray.

It is checked whether the ray encounters the voxel corresponding to the wall of the structure (S4250). When it is determined that the ray encounters the voxel corresponding to the wall of the structure, the position where the ray encounters the voxel is recorded in inVolumePoint (S4260). The values of the respective unit parts that form the voxel on a straight line, that is, volume data and peripheral values, are checked along a given viewing vector or in the direction of a camera in the axial image input to the screen. Accordingly, it is checked whether the values of the respective units parts and the peripheral values correspond to the density value of the wall of the structure.

It is checked whether the ray encounters the voxel corresponding to the wall of the structure (S4270). When it is determined that the ray encounters the voxel corresponding to the wall of the structure, the position where the ray encounters the wall of the structure is recorded in outVolumePoint (S4280).

The result of a middle point between the inVolumePoint and the outVolumePoint is output. It is possible to convert the point input from the

volume rendering image into the center of the structure on the basis of the result (S4290).

As mentioned above, in FIG. 5, a black voxel has the density value of a human body. A first point in the direction where an arrow moves forward shows a state before entering the inside of the structure. A second point shows the inside of the structure. A third point shows a state right after passing through the inside of the structure.

When endoscopy diagnoses are performed by the virtual endoscopy system, it is very useful if a user has information on peripheral structures. In particular, medical staffs want a reformation image including the path passing through the central line of the structure.

In response to such a request of the medical staffs, according to the virtual endoscopy system of the present invention, the reformation image including the path is shown as the reference image. Also, the image is created to rotate 360°. Therefore, it is possible to obtain correct information on peripheral structures.

FIG. 7 explains the generation of the cross-sectional reformation image including the path according to the present invention. FIG. 8 explains the generation of a cross-sectional reformation image parallel to or vertical to the path according to the present invention.

Referring to FIGs. 7 and 8, a multi-planar reformation image including a straight or curved path can be formed by generating scan lines one by one in a uniform direction set by the user in the respective points on

the path according to the manipulation of the mouse by the user. That is, when the cross-sectional image is displayed on a 3D image, the multi-planar reformation image cut through a curved line on the 3D image having various forms as well as an image cut by a straight line can be generated and displayed. Because the path MPR image formed at this time displays information on the peripheral structures centering on the path passing through the central line of the structure, the path MPR image is very useful to the medical teams when the endoscopy diagnoses are performed.

According to the present invention, a curved planar reformation is performed in a direction where the 3D image is observed in forming the multi-planar reformation image using a virtual endoscopy path. Accordingly, it is possible to spread the overall length of the anatomical structure desired to be seen. Also, it is possible to rotate a curved planar reformation image using the virtual endoscopy path as an actual axis by changing the curved planar reformation image according to the rotation of the 3D image.

As shown in FIG. 8, in the case of reforming a cross-sectional plane of a straight line interface method, which is parallel to the virtual endoscopy path in the point of view of the virtual endoscope, it is possible to freely rotate the cross-sectional plane using the direction of the virtual endoscopy path as an axis. The reformation of the cross-sectional plane of the straight line interface method, which is vertical to the virtual endoscopy path in the point of the virtual endoscope, can be realized so as to continuously show the vertical cross-sectional plane of the structure to be

observed, while moving according to the movement of the point of view of the virtual endoscope.

That is, it is possible to easily understand the view of the virtual endoscopy image through the multi-planar reformation image by selecting and using an appropriate multi-planar reformation method according to the characteristics of the structure to be observed in the point of view of the virtual endoscope.

A method of spreading the overall length of the anatomical structure desired to be seen by performing the curved planar reformation in the direction where the 3D image is observed will be realized as follows.

Information on a curved line path that follows the center of the structure is expressed as points separated from each other by one. The points are stored as a 3D coordinate system value (x, y, z). Therefore, a curved planar reformation image is obtained following a straight line that passes one point on the path because one point on the path and the viewing vector are known.

A value corresponding to a pixel is obtained, while moving forward using a directional vector until getting out of the boundary of the volume data starting from each point. One line of a reformation image is obtained when the above operation is performed with respect to one point.

Therefore, when the above operation is performed with respect to all of the 3D points, a perfect reformation image is formed. FIG. 7 shows the processes.

As shown in FIG. 8, in order to reform the cross-sectional plane parallel to or vertical to the path, a normal vector in a point on the path is used. The normal vector value of each point that forms the path is a value obtained by differentiating the formula of a curved line. Therefore, in order to reform the plane parallel to one point on the path, a plane reformation image is formed by a plane including a point on the path and a point on the normal vector. Because a plurality of planes can be formed, it is preferable that a plane is selected by the manipulation of the user.

Also, one plane is determined because a cross-sectional plane vertical to one point on the path is vertical to one point and the normal vector. Therefore, when a point on the path is selected, it is possible to form the plane reformation image by the plane whose normal vector is the normal vector of the point.

A method of obtaining a 3D effect on the axial image, which is another characteristic of the present invention, will now be described in more detail.

FIG. 9 explains the 3D controlling of a camera in the axial image according to the present invention. In particular, the manipulation of the direction on the plane and the manipulation of the direction on the depth will now be described in detail.

Referring to FIG. 9, the position to be observed can be designated by clicking the mouse in the 3D image created by the axial image or the volume rendering image. The virtual endoscopy viewing direction can be

controlled to the planar direction of the x, y coordinate and the depth direction of the z coordinate in the axial image and the 3D image.

According to the present invention, the user can easily select and grasp the position of the virtual endoscope by newly rendering the virtual endoscopy image whenever the point of view and the viewing direction are changed. Accordingly, it is possible to obtain the 3D image effect in the axial image.

The manipulation method will now be described in the point of view of the user who uses the virtual endoscope.

The position and direction of the current camera are marked with red in the volume rendering viewer and the axial image. In order to change the position of the camera, for example, the user clicks the left mouse button. In order to change the direction of the camera, for example, the user clicks the right mouse button. However, when a common axial image is used as the reference image of the virtual endoscope, it is difficult to display the depth direction on the two dimensions.

However, according to the virtual endoscopy system of the present invention, it is possible to change the direction mode of the z coordinate as shown in FIG. 8. That is, a direction conversion mode is changed by a toggle method when the user clicks the arrow with the right mouse button. In the case of red, planar direction controlling can be performed. In the case of blue, depth direction controlling can be performed. In the case of red, the direction changes on a plane vertical to the viewing direction of the

camera according to the movement of the mouse. In the case of blue, the direction changes on a plane including the vector of the viewing direction of the camera. A 3D manipulation can be performed on the axial image.

FIG. 10 shows the 3D volume rendering image used as the reference image of the virtual endoscopy system according to the present invention. In particular, an image obtained by visualizing a bronchus by the three-dimensional volume rendering in order to perform an endoscopy on the bronchus is shown.

Referring to FIG. 10, in order to look at the bronchus by the virtual endoscopy, classification is performed by the density value corresponding to the bronchus in the 3D volume rendering, unnecessary parts are deleted so that the bronchus is shown, and the viewing direction of the camera or the user is controlled.

FIG. 11 shows an example of loading a screen provided by a preferred virtual endoscopy system according to the present invention on the basis of the 3D volume rendering image of FIG. 10.

Referring to FIG. 11, in the virtual endoscopy system, the four viewers shown in FIG. 2 are shown. The position of the camera is marked with red in each viewer. An example of setting a direct path in the 3D reference image, which is a characteristic of the present invention, is shown.

When the path is set by the manipulation of the user, a multi-planar reformation image including the path is generated in a MPR path viewer.

The position of the camera is displayed in the multi-planar reformation image including the path. In order to change the direction of the multi-planar reformation image, including the path, the mouse is used in the volume rendering image viewer. The direction of the reformation image is marked with a blue line in the 3D volume rendering viewer among the four viewers.

FIG. 12 shows a screen that provides a function of arbitrarily modifying the path once designated by the user in FIG. 11 in the preferred virtual endoscopy system according to the present invention.

Referring to FIG. 12, processes of directly modifying the path in the 3D reference image are shown. The path is modified by moving the point on the path with the mouse.

Equipment for measuring a length on the path created as such is included in the virtual endoscopy system according to the present invention for the convenience of the user.

Various changes in form and details may be made in the virtual endoscopy system, the virtual endoscopy method using the same, and the computer readable recording media for storing the method, without departing from the spirit and scope of the invention. The virtual endoscopy system, the virtual endoscopy method using the same, and the computer readable recording media for storing the method are not limited to the preferred embodiment.

For example, a light pen, the keyboard, and various input

apparatuses as well as the mouse can be used as the input means. The virtual endoscopy system, the virtual endoscopy method using the same, and the computer readable recording media for storing the method can be widely applied to the designing and constructing of 3D structures such as automobiles, ships, and buildings, as well as systems for processing medical images.

As mentioned above, according to the virtual endoscopy system according to the present invention, the user can easily define and modify the path using the image generated by the volume rendering as the reference image without preprocessing on the 3D volume data. The MPR image is generated along the set path. Accordingly, it is possible to more easily understand the circumstances around the structure.

The above-mentioned virtual endoscopy that is an integrated environment of various kinds of medical images is obtained by generalizing high technologies. According to the present invention, the virtual endoscopy can be developed into an integrated system including various images and technologies.

While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

As mentioned above, because the virtual endoscope according to the present invention is not inserted into a patient, it is possible to look at the insides of organs without pain.

Also, according to the prior endoscopy, it is possible to observe the insides of the organs only in the direction where the camera moves forward. However, according to the virtual endoscopy of the present invention, it is possible to observe the insides of the organs in the direction where the camera moves backward. Accordingly, the virtual endoscopy according to the present invention is very useful for diagnoses.

The virtual endoscopy system has not been widely used because it is difficult to manipulate the virtual endoscopy system due to the inefficiency of interface. However, according to the present invention, the user can easily manipulate the camera and various reference images can be shown. Accordingly, it is possible to improve the efficiency of the virtual endoscopy.

**WHAT IS CLAIMED IS:**

1. A virtual endoscopy system, comprising:

an input/storage unit for reading or transferring the 3-dimensional volume data from source devices into the target devices for further processing;

an endoscopy image processing unit for analyzing and displaying spatial distribution of the characteristics to a 3D image on the basis of data stored in the input/storage unit, processing the 3D image so as to display it as a reference image, generating an endoscopy image along a predetermined path directly displayed on the reference image, and processing the endoscopy image so as to display it;.

a display for displaying the reference image and the endoscopy image along the path; and

an input unit for letting a user designate the path from the reference image.

2. The virtual endoscopy system of claim 1, wherein the endoscopy image processing unit comprises:

a reference image processor for processing the 3D reference image so as to display it from the volume data stored in the input/storage unit, receiving a predetermined path that passes through an inner structure whose endoscopy image is to be seen through the input means in the form of predetermined curved data on the reference image, and processing the

curved data;

a path converter for determining the position of a voxel corresponding to the wall of the inner structure whose endoscopy image is to be seen in the volume data from the path input to the reference image processor, and correcting a path so that the path can actually pass through the inner structure; and

a multi-planar reformation image composer for generating a multi-planar reformation image including the path along the corrected path obtained by the path converter.

3. A virtual endoscopy method for storing primitive image data, classifying the density value of the stored primitive image data, and displaying a virtual endoscope, comprising:

(a) generating a volume rendering image corresponding to a part to be observed from the 3D volume data;

(b) displaying the generated volume rendering image, an axial image, a virtual endoscopy image, and a path MPR image;

(c) updating display of the path MPR image as a path is set in either the axial image or a 3D volume rendering image according to the manipulation of a user;

(d) checking whether the camera position is requested to be changed according to the manipulation of the user; and

(e) generating virtual endoscopy image data according to the

change of the camera position and updating the virtual endoscopy image and the axial image on the basis of the generated virtual endoscopy image, when the camera position is requested to be changed.

4. The method of claim 3, further comprising (f) checking whether it is requested to reform the volume rendering image according to the manipulation of the user, and returning to the step (a) when it is determined that it is requested to reform the volume rendering image.

5. The method of claim 3, wherein the step (c) further comprises:

(c-1) generating the formula of a 3D curved line by adding the control point of the formula of the curved line as a point that is designated according to the manipulation of the user in either the axial image or the 3D volume rendering image;

(c-2) generating a curved line path using the formula of the 3D curved line; and

(c-3) storing corresponding points at predetermined intervals along the generated curved line path.

6. The method of claim 5, wherein the step (c-2) further comprises the step of converting the 3D volume rendering image into the center of the structure when the 3D volume rendering image is used as the reference image.

7. The method of claim 6, wherein the step of converting the 3D volume rendering image into the center of the structure comprises:

setting the minimum value and the maximum value of the depth to be examined according to the input of a mouse to the axial image drawn by volume rendering;

converting a point of a screen coordinate system into a point in a spatial coordinate system by multiplying time inverse matrices by each other;

casting predetermined ray from the center of projection;

firstly storing a corresponding position when the casted ray firstly encounters a voxel corresponding to the wall of a structure;

secondly storing a corresponding position when the casted ray secondly encounters the voxel corresponding to the wall of the structure; and

generating an intermediate point result on the basis of the firstly stored position and the secondly stored position.

8. The method of claim 3, wherein the camera displays the volume rendering image, the axial image, the virtual endoscopy image, and the path MPR image using a predetermined viewing vector; updates the volume rendering image, the axial image, the virtual endoscopy image, and the path MPR image using a changed viewing vector obtained by controlling the viewing vector; and obtains a 3D image effect on the axial

image.

9. A computer readable recording media for storing a program including a method for displaying a virtual endoscope by storing primitive image data and classifying the density value of the stored primitive image data, comprising:

(a) generating a volume rendering image corresponding to a part to be observed from the 3D volume data;

(b) displaying the generated volume rendering image, an axial image, a virtual endoscopy image, and a path MPR;

(c) updating display of the path MPR image as a path is set in either the axial image or a 3D volume rendering image according to the manipulation of a user;

(d) checking whether the camera position is requested to be changed according to the manipulation of the user; and

(e) generating virtual endoscopy image data according to the change of camera position and updating the virtual endoscopy image and the axial image on the basis of the generated virtual endoscopy image, when the camera position is requested to be changed.

FIG.1

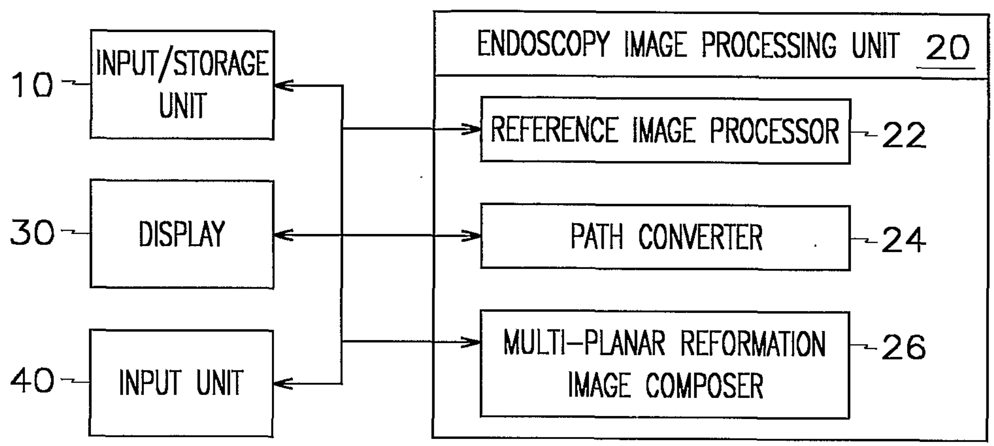

10
INPUT/STORAGE UNIT
30
DISPLAY
40
INPUT UNIT
ENDOSCOPY IMAGE PROCESSING UNIT 20
REFERENCE IMAGE PROCESSOR
22
PATH CONVERTER
24
MULTI-PLANAR REFORMATION IMAGE COMPOSER
26

FIG.2

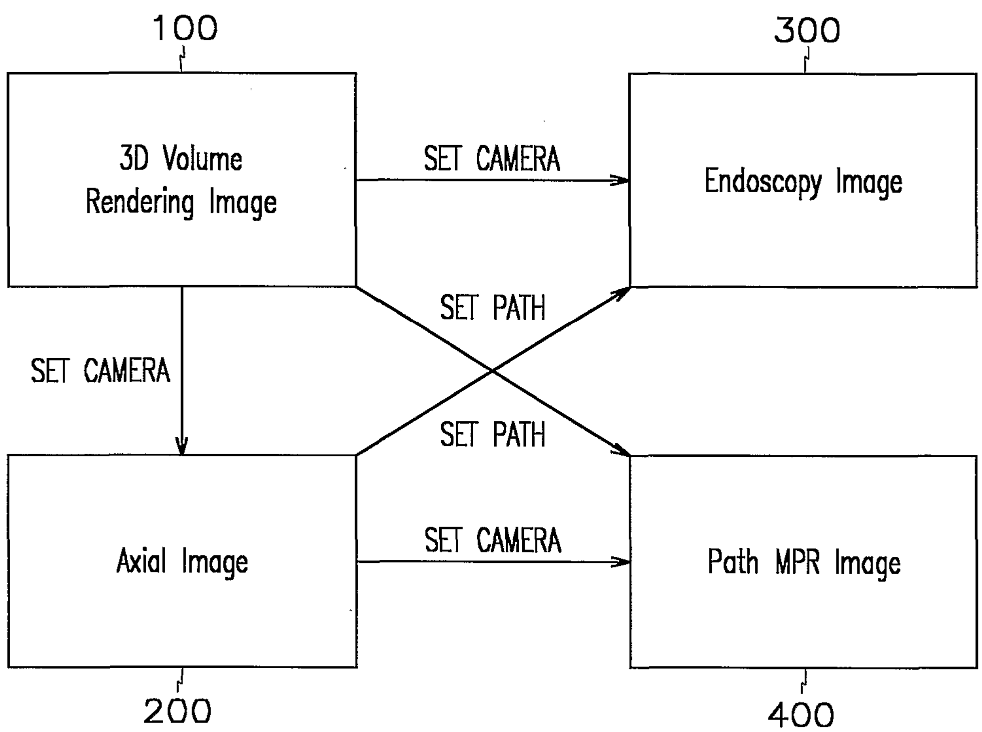

100
3D Volume
Rendering Image
300
SET CAMERA
Endoscopy Image
SET PATH
SET CAMERA
SET PATH
Axial Image
SET CAMERA
Path MPR Image
200
400

FIG.3

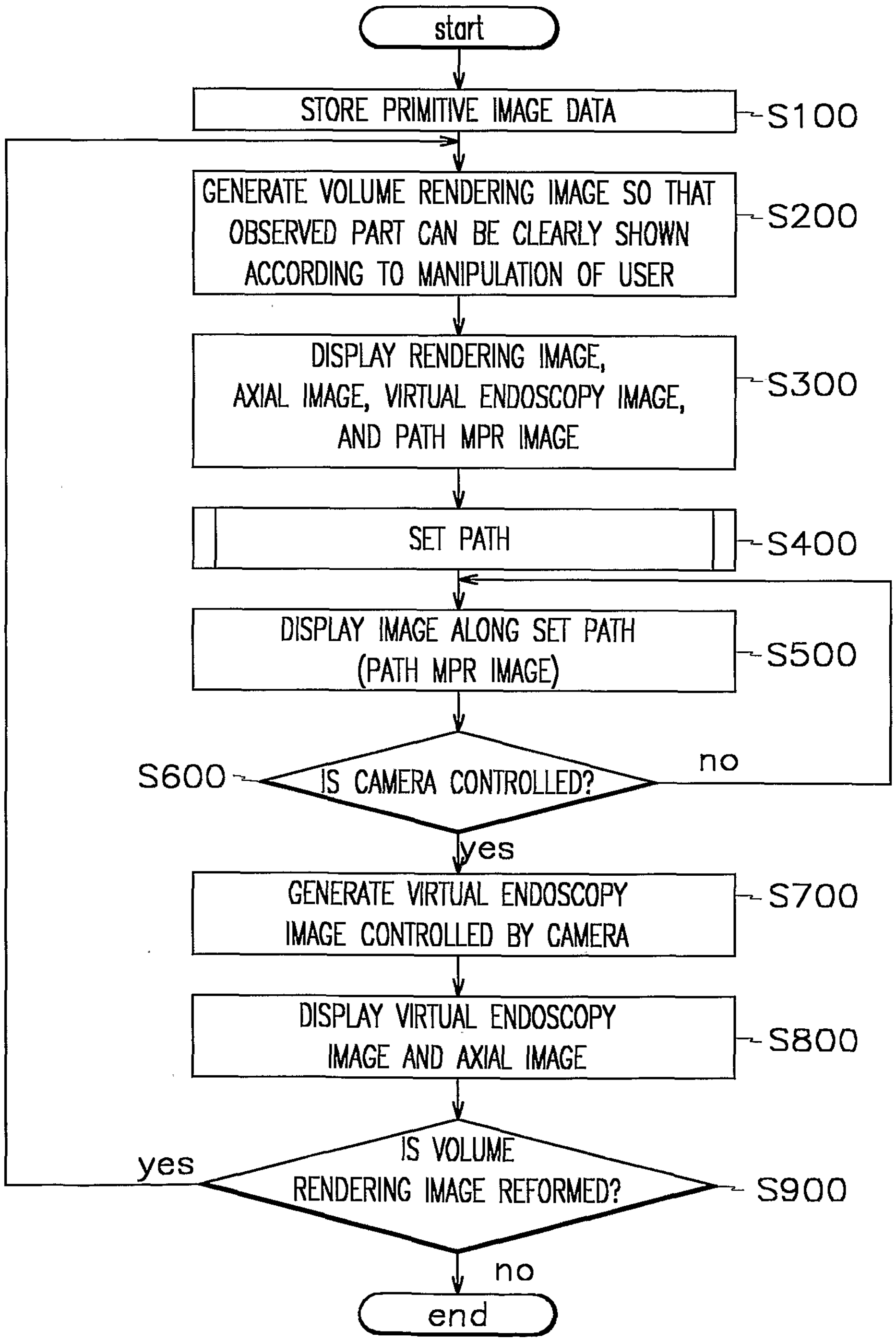

start
STORE PRIMITIVE IMAGE DATA
S100
GENERATE VOLUME RENDERING IMAGE SO THAT OBSERVED PART CAN BE CLEARLY SHOWN ACCORDING TO MANIPULATION OF USER
S200
DISPLAY RENDERING IMAGE, AXIAL IMAGE, VIRTUAL ENDOSCOPY IMAGE, AND PATH MPR IMAGE
S300
SET PATH
S400
DISPLAY IMAGE ALONG SET PATH (PATH MPR IMAGE)
S500
S600
IS CAMERA CONTROLLED?
no
yes
GENERATE VIRTUAL ENDOSCOPY IMAGE CONTROLLED BY CAMERA
S700
DISPLAY VIRTUAL ENDOSCOPY IMAGE AND AXIAL IMAGE
S800
yes
IS VOLUME RENDERING IMAGE REFORMED?
S900
no
end

FIG.4

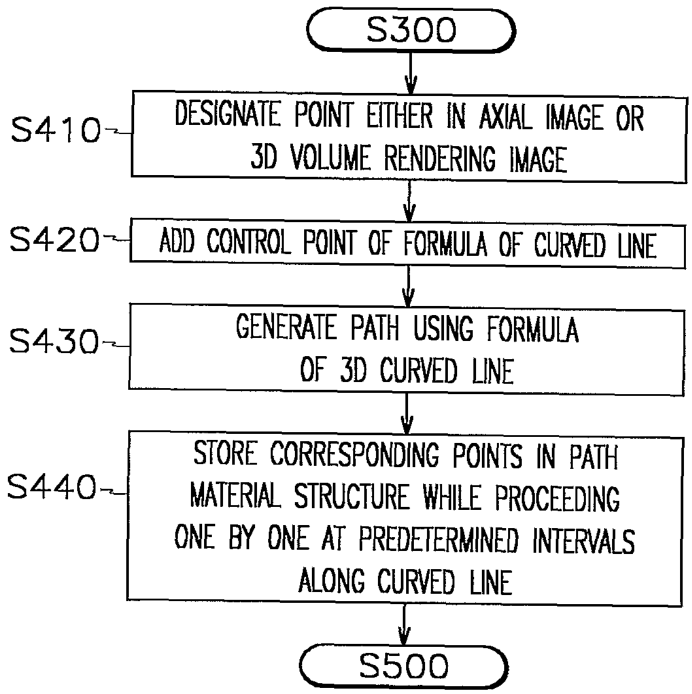

S300
S410
DESIGNATE POINT EITHER IN AXIAL IMAGE OR 3D VOLUME RENDERING IMAGE
S420
ADD CONTROL POINT OF FORMULA OF CURVED LINE
S430
GENERATE PATH USING FORMULA OF 3D CURVED LINE
S440
STORE CORRESPONDING POINTS IN PATH MATERIAL STRUCTURE WHILE PROCEEDING ONE BY ONE AT PREDETERMINED INTERVALS ALONG CURVED LINE
S500

FIG.5

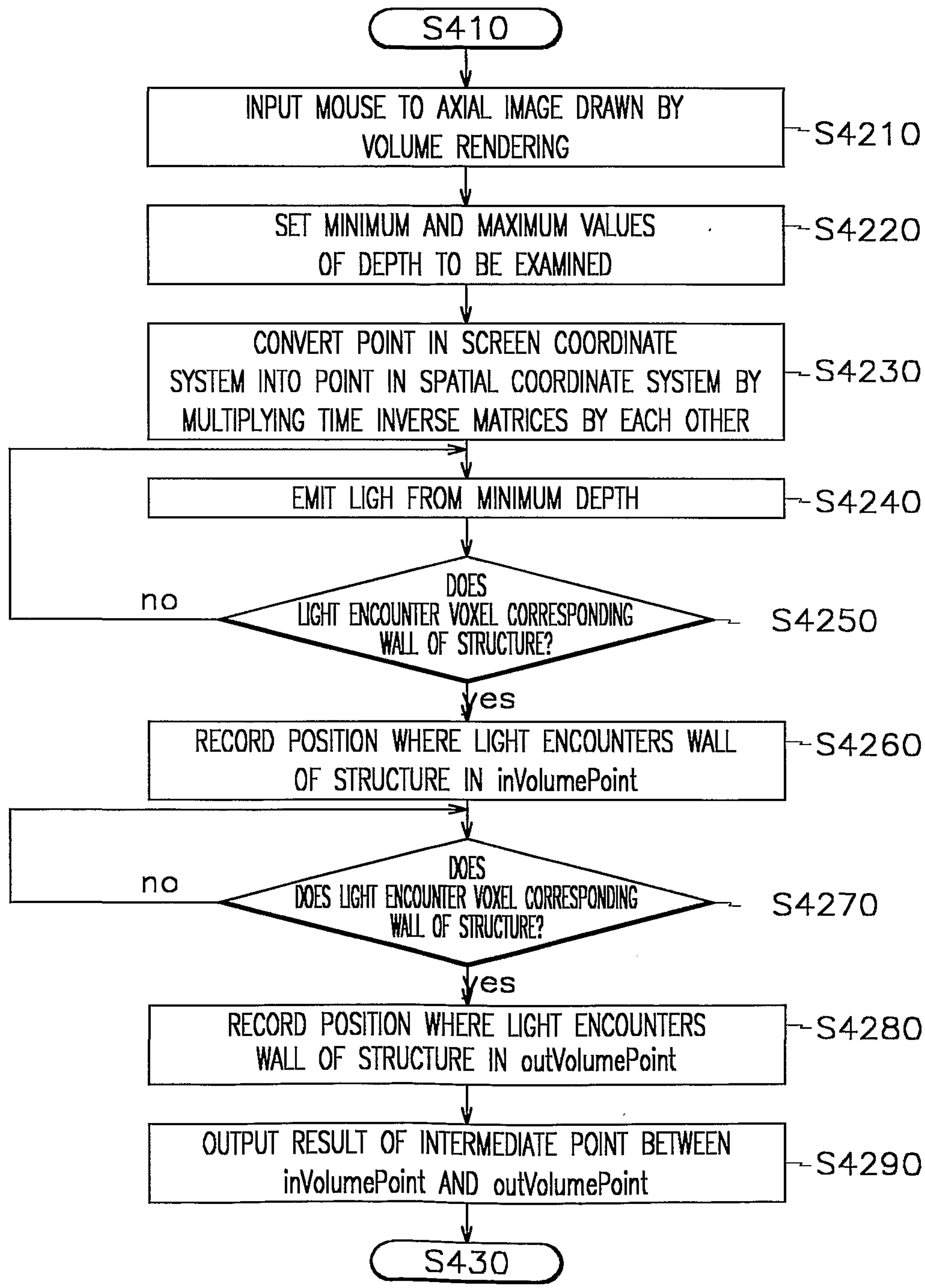

S410
INPUT MOUSE TO AXIAL IMAGE DRAWN BY VOLUME RENDERING
S4210
SET MINIMUM AND MAXIMUM VALUES OF DEPTH TO BE EXAMINED
S4220
CONVERT POINT IN SCREEN COORDINATE SYSTEM INTO POINT IN SPATIAL COORDINATE SYSTEM BY MULTIPLYING TIME INVERSE MATRICES BY EACH OTHER
S4230
EMIT LIGH FROM MINIMUM DEPTH
S4240
DOES LIGHT ENCOUNTER VOXEL CORRESPONDING WALL OF STRUCTURE?
S4250
no
yes
RECORD POSITION WHERE LIGHT ENCOUNTERS WALL OF STRUCTURE IN inVolumePoint
S4260
DOES DOES LIGHT ENCOUNTER VOXEL CORRESPONDING WALL OF STRUCTURE?
S4270
no
yes
RECORD POSITION WHERE LIGHT ENCOUNTERS WALL OF STRUCTURE IN outVolumePoint
S4280
OUTPUT RESULT OF INTERMEDIATE POINT BETWEEN inVolumePoint AND outVolumePoint
S4290
S430

FIG.6

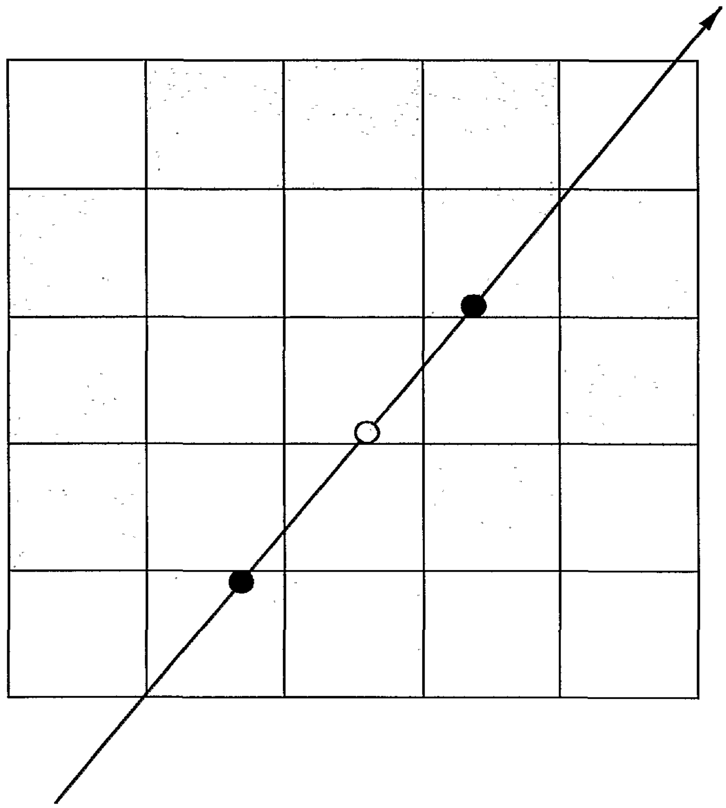


FIG.7

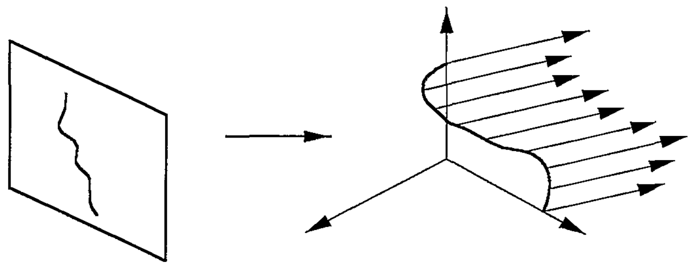


FIG.8

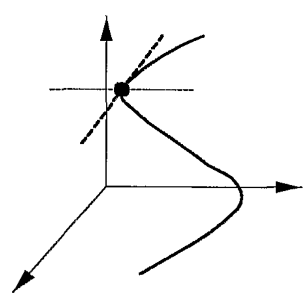


FIG.9

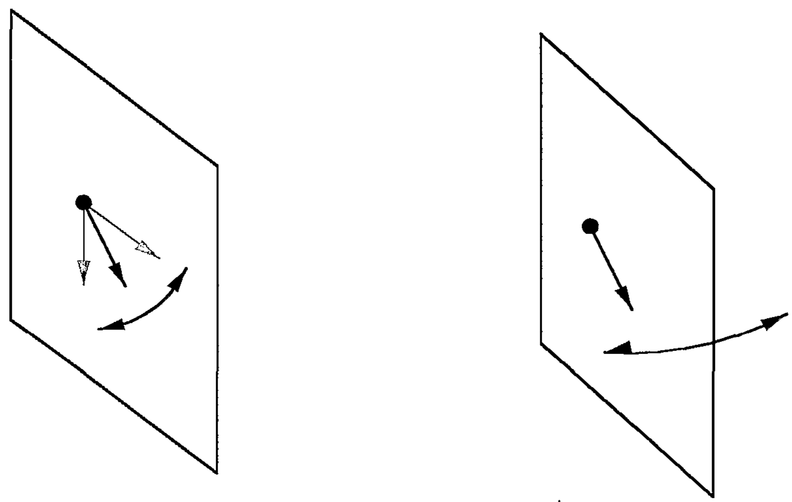


FIG.10

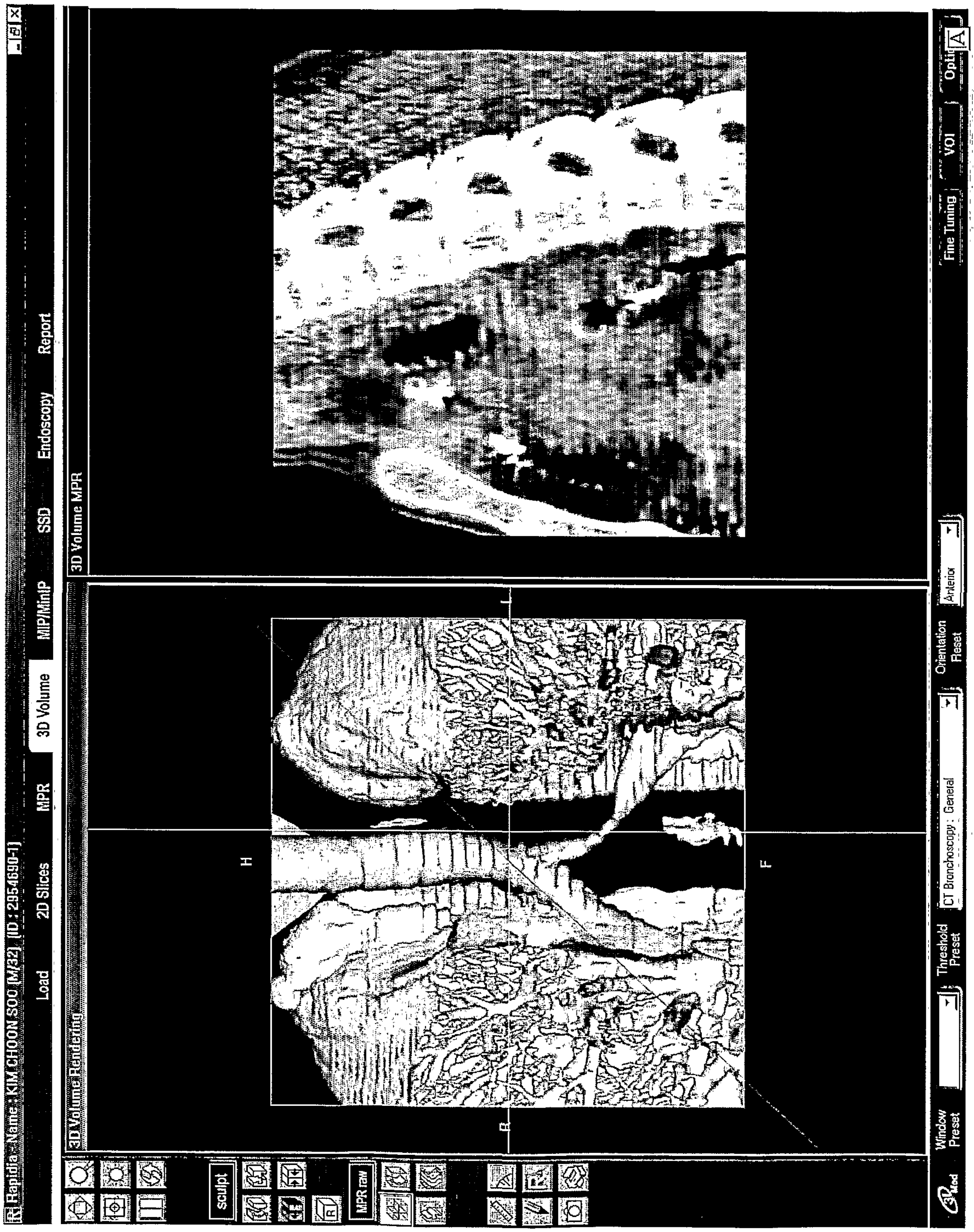

Load
2D Slices
MPR
3D Volume
MIP/MinIP
SSD
Endoscopy
Report
3D Volume Rendering
3D Volume MPR
sculpt
MPR raw
Window Preset
Threshold Preset
CT Bronchoscopy : General
Orientation Reset
Anterior
Fine Tuning
VOI

FIG.11

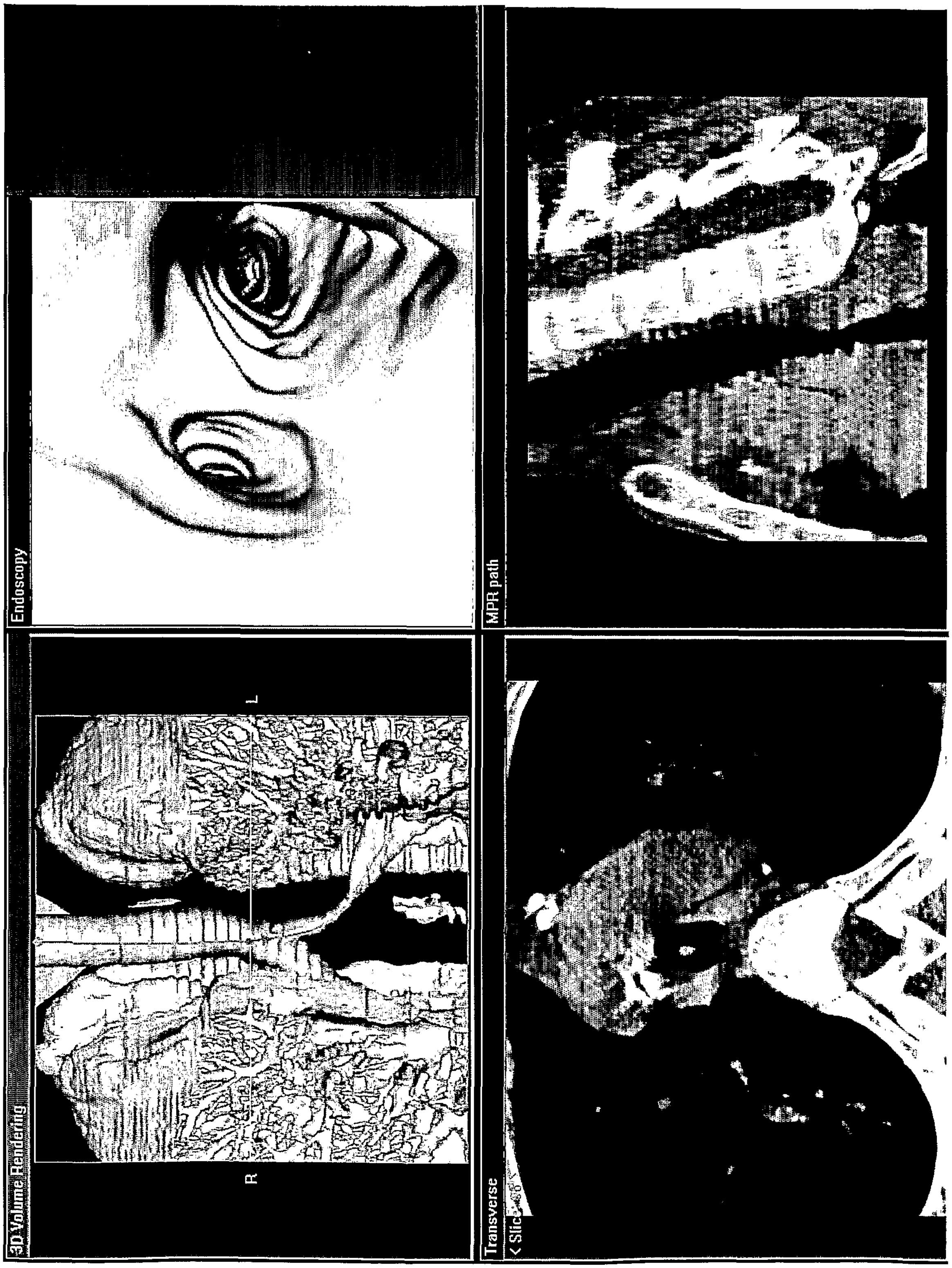
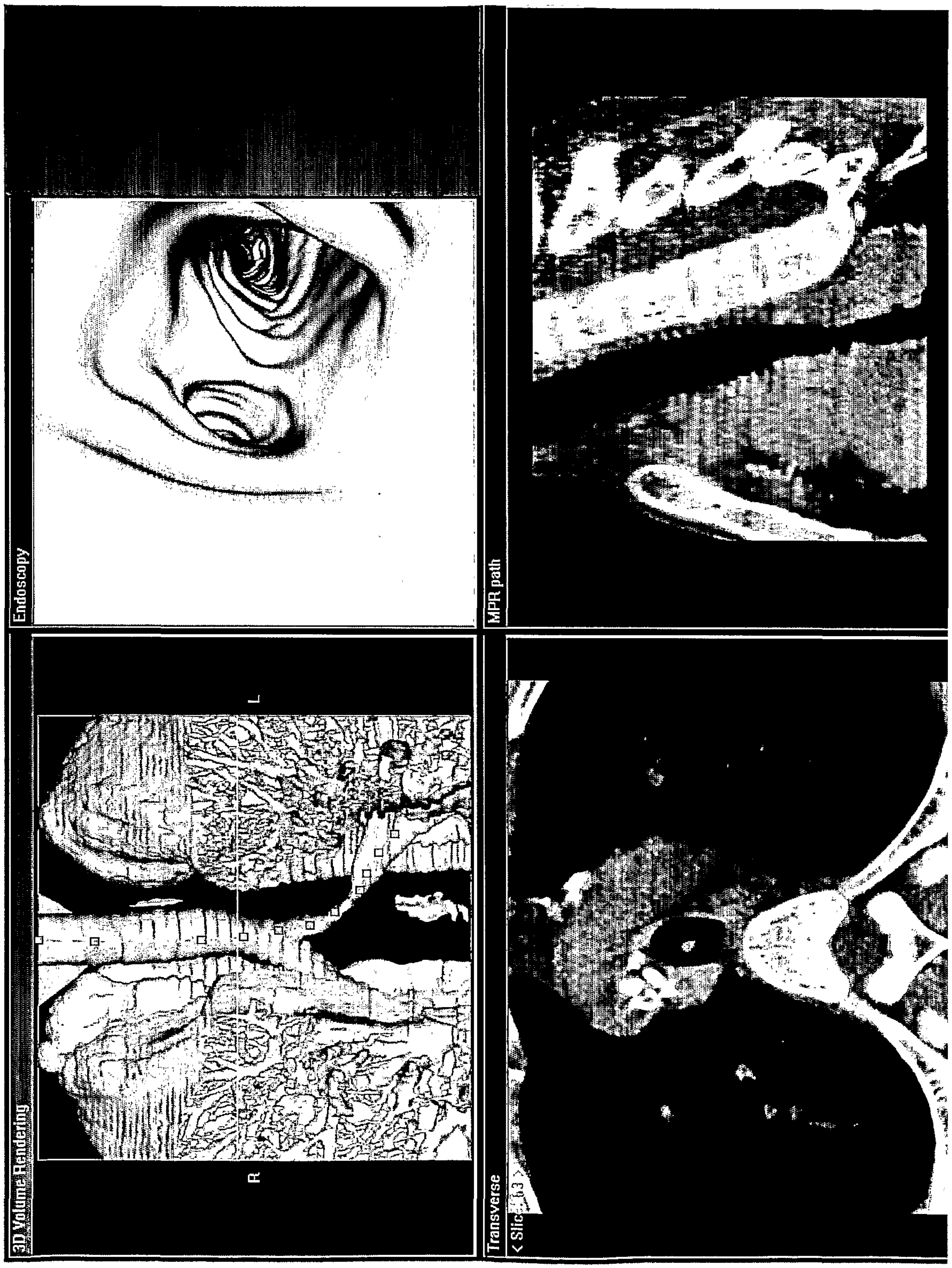


FIG.12



# INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR01/02017

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC7 A61B 1/04**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC7 G06T, G09B, A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Patents and applications for inventions since 1975
Korean Utility models and applications for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| | WO 00/55812 A (The Research Foundation of State University of New York) 21 Sep. 2000 | |
| X | | 1 |
| Y | | 2-6, 8-9 |
| A | | 7 |
| | WO 98/11524 A (The Research Foundation of State University of New York) 19 Mar. 1998 | |
| X | | 1 |
| Y | | 2-6, 8-9 |
| A | | 7 |
| | US 5,986,662 A (Vital Images, Inc.) 16, Nov. 1999 | |
| X | | 3-4, 9 |
| Y | | 1-2, 5-6, 8 |
| A | | 7 |
| A | US 6,083,162 A (Wake Forest University) 4, Jul. 2000 | 1-9 |

☐ Further documents are listed in the continuation of Box C.　☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 13 MARCH 2002 (13.03.2002) | 13 MARCH 2002 (13.03.2002) |

| Name and mailing address of the ISA/KR | Authorized officer |
|---|---|
| Korean Intellectual Property Office<br>Government Complex-Daejeon, 920 Dunsan-dong, Seo-gu, Daejeon Metropolitan City 302-701, Republic of Korea | SHIN, Un Cheol |
| Facsimile No. 82-42-472-7140 | Telephone No. 82-42-481-5585 |